Ease-of-Use of Tactile Interaction for Novice Older Adults

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Abstract. Usability, particularly ease-of-use, is a main factor affecting the acceptance of technologies by older adults. Mobile devices offer great possibilities for well-being applications, but they are often equipped with touchscreen. In order to evaluate the ease-of-use of tactile interaction, this study compares the performances of 16 novice (mean age 74) and 8 experienced older adults (mean 75) during the execution of drag-and-drop interaction for achieving tactile puzzle games on smartphone and tablet, with pen and fingers. Results show that novice users were able accomplish interaction accurately with longer times but no significant difference of errors of accuracy.

Keywords. Human-computer interaction; interaction techniques; older adults; touchscreen, drag-and-drop, errors of accuracy, ease-of-use, usability.

1 Introduction

Mobile devices offer great possibilities for well-being applications destined to older populations. Mobile technologies are also being developed to help older users to overcome age related declines in cognitive, motor and perceptual skills. Unfortunately, the adoption of technologies by this population is very limited [1]. In France, the availability of touchscreen mobile devices in the market and the reduction of the cost for devices and services (i.e. subscription for mobile connections) have a great impact on the number of elderly using mobile Internet: 16.4 % of people aged 60 to 74 years old and 3.1% of people aged 75 years old or older in the end of 2012 according to a report of INSEE (National Institute of Statistics and Economics Studies) [2]. They are still a small part of the population when compared to the younger age groups: 75% of 15 to 29 years old or 50.8% of 30 to 44 years old people. In Europe, 42% of people aged 55 to 74 years old declared a regular internet use (against 93% of 16 to 24 or 78% of 25 to 54 years old) but only 12% of this population used mobile devices for internet access (against 58% of 16 to 24 or 36% of 25 to 54 years old) [3].

Barnard et al (2013) [1] defined two stages for technology acceptance : first, the intention to use, referring to a behavior that is affected by performance expectancy, effort expectancy, social influence and facilitating conditions ; second, the usability, i.e. "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments" (ISO 9241). According to Lee and Coughlin (2014), enhancing usability means to meet older adults' needs, preventing errors and providing help to control [4]. They describe usability as "ease of learning and use" [4]. Renaud and van Bijon (2008) consider ease of use a determining factor for intention to use and consequently for technology acceptance among older adults [5].

Mobile devices are often equipped with touchscreen. But is tactile interaction easy to use by older adults? The aim of this study is to evaluate the ease-of-use of tactile interaction. Previous studies on human-computer interaction have discussed about the effects of prior experience on older adults performances [6]. So we compare the performances (time and error rate) of older adults with and without previous experience with touchscreen devices. Our main hypothesis is that tactile interaction is easy to use. Therefore, we expect that novices and experienced subjects would have similar performances during the drag-and-drop interaction for solving tactile puzzles on smartphone and tablet, with pen and fingers.

The remainder of this paper is organized as follows. Section 2 discuss usability as a determining factor for technology acceptance and the ease of use of tactile interaction for novice older adults, positioning this work in relation to the previous studies and justifying the need of studying and improving tactile interaction. Section 3 describes the experience. Section 4 shows the results of the statistical analysis. Results are discussed on section 5 followed by conclusions on section 6.

2 Related Work

2.1 Technology acceptance for older adults

Acceptance has been defined as an attitude towards technologies, referring to early phase and essential step to an adoption process. Adoption is the process by which users embrace technologies, since the moment when potential users become interested to a technology until the moment the use of it has an impact in their daily lives [5].

Ease-of-use is one of the main factors of technology acceptance according to several authors. In a review of the literature, Peek et al (2014) found that low ease of use is a key concern during pre-implementation acceptance factors of technologies for aging in place [7]. According to Lee and Coughlin (2014), "ease of learning and use" is one of the ten factors facilitating or determining the adoption of technology by this group of users [4]. Ease of learning and use has been considered a predictor for technology acceptance or rejection by Renaud and van Bijon (2008) [5].

Older adults are a heterogeneous population. Chronological age is not enough for describing the characteristics of adults aged 65 years old or more because aging is an individual process [8]. In addition to the physical and cognitive declines related to age, earlier experiences can affect older adults perception of their own ability to use new technologies [8]. Gudur et al (2013) have demonstrated that previous experience with computers and technologies affects positively the self-confidence of older adults for interaction tasks [9]. By consequence, previous experience affects their attitudes and expectations towards technologies or even acceptance [1]. Older adults who did not learn how to use a computer during their professional carrier or education need more training to progress and feel confident compared to younger adults [1]. Technologies, interfaces and interaction techniques should be easy to learn and use in order to overcome lower technology literacy [4].

2.2 Ease-of-use of tactile interaction for novice older adults

Tactile interaction is considered easy to learn and use because direct interaction on the screen reduces the cognitive workload demanding less eye-control coordination than traditional input devices [10]. Direct interaction on touchscreen has been recommended for older adults as easier to use [10], reducing the gap of performances between adults and older adults when compared to traditional input devices [11].

When using new technologies, people might feel uncomfortable if they don't know how to control it [12]. Anxiety is related to lack of confidence and this feeling can affect the perceived benefit [4], disturbing the use of intuitive interaction. It also affects older user's performances because it causes distraction. The absence of physical keyboard and mouse diminishes the anxiety towards technologies, affecting positively user's attitudes [10]. Familiarity with the interaction and interfaces influences the attitudes towards technologies [4]. Systems and interaction techniques designed to prevent mistakes and support interaction help to increase confidence [9].

2.3 Difficulties related to tactile interaction

8% of French users, all age groups included, complained about difficulties for using tactile interaction [2]. Older users have reported several problems during touchscreen use as discouraging for the acceptance of technologies and disturbing for achieving interaction, such as lack of control, small targets, difficulties for error recovering among others.

The review of the literature of studies of tactile interaction of older adults describes problems related to the situations of use or users' abilities.

Concerning the situations of use, several factors have been reported. Small screen devices usually present small targets, difficult to acquire, especially during finger interaction [13]. Pen interaction has been indicated to improve accuracy, especially on small touchscreen devices [14]. Concerning the gestures of interaction that have been evaluated, tapping has been considered intuitive and faster than dragging [11, 15] but it requires bigger targets. Drag-and-drop allows accurate interaction on small devices [14] and performances increase rapidly with practice [15].

Concerning the abilities of older users, visually impaired users were able to accomplish drag-and-drop interaction during card games on mobile devices [6]. This gesture of interaction has been studied to improve text entry tasks for older users with tremor [16], [17]. During mouse interaction, dragging elements helps to track the cursor on the screen and it has been evaluated for cognitive impaired users [18]. The metaphor of drag interaction gesture is closer to the reality.

Familiar and ludic activities help novice users to discover the manipulation of devices and learning interaction [19]. When playing a game, an error is not supposed to be serious and discouraging because it doesn't have implications on real life. That is one of the reasons the present study evaluates tactile interaction during the execution of puzzle games.

3 Methods

Ease-of-use is one of the main factors of usability affecting technology acceptance [4, 7]. As mobile devices are often equipped with touchscreen, we want to investigate if tactile interaction is easy to use. As already presented in the Section 2, previous experience with technologies affects users' performances. So we will compare two groups of subjects: older adults with and without previous experience with touchscreen. Our hypothesis is that novice and experienced older adults will have similar performances.

HCI studies usually assess interaction performances through time and error rate. In order to reproduce different situations of use of mobile touchscreen, we will evaluate performances on smartphone and tablet, with pen and fingers and two levels of difficulty (corresponding to two accuracy requirements). The easier level requires 80% of accuracy and the higher level requires 95% of accuracy for the final positioning. These two levels will be treated indistinctly. As a complement, we will search for effects of screen size and interaction techniques. This study extends the analysis of a previous study about supplementary attempts for positioning the targets [14].

3.1 The interactive system

The system "Puzzle Touch" is consisted of tactile puzzle games so older adults without previous experience with touchscreen would feel confident to participate of the experience by the familiarity with the proposed activity [19].

The main task is moving the puzzle pieces to place them on a grid (drag-and-drop). Targets sizes (the correct emplacement for a puzzle piece) were 19x19mm on the smartphone (85 pixels width) and 35x35mm (195 pixels width) on the tablet. 12 squared pieces are randomly placed on the mid bottom of the screen and a 3x4 grid with a watermark is displayed on the mid top. In order to compensate the lack of spacing between pieces, they are contoured by a 1mm dark border. When the final position of a puzzle piece is validated, there is a visual feedback (a flash effect) and the piece is fixed on the grid.

3.2 Material

A 5.5 inches screen smartphone (Galaxy Note II with a WXGA 1280x720 Super AMOLED touchscreen) and a 10.1 inches screen tablet (Galaxy Note 10.1 with a WXGA 1280x800 LCD touchscreen) were used for this experiment. Both devices allow interaction with pen or fingers.

3.3 Procedure

Recruitment took place on associations, clubs and libraries frequented by older adults in Toulouse, France, where demonstration meetings were organized to explain the purposes of the study. Being aged 65 or older was the unique criteria of inclusion. Volunteers had an individual appointment for the experiment.

The individual session started by a familiarization phase with at least four complete interactions with both interaction techniques on the tablet and on the smartphone. After given their formal consent, they passed eyesight control tests and answered questionnaires about their motor abilities, previous experience with technologies and particularly frequency of use of touchscreen devices.

Subjects were told to install themselves comfortably, they were seated and the devices were horizontally placed on a table on portrait mode. Participants were told to complete the games accurately. Every subject played eight tactile puzzle games: with pen and finger interaction, on smartphone and tablet and two sets on different requirement levels (first the easier level, requiring 80% accuracy, and then the difficult one, requiring 95% of accuracy). The order of the use of devices and interaction techniques has been counter-balanced.

3.4 Measures

We assessed mean time of movement and number of errors of accuracy as evaluation criteria.

Time of movement refers to the time the subject spent moving the pieces before reaching their correspondent target (TM). It does not include reflection time.

The number of errors of accuracy was verified according to the position of the dropped piece on the game. One error of accuracy is counted once the puzzle piece is covering at least 50% of its right emplacement but should be corrected positioned to meet the accuracy requirements of the game. The others movements of the puzzle pieces have been considered as a strategy to solve the puzzle. The number of errors of accuracy (EA) [14] counts the number of supplementary attempts for reaching a target.

4 Results

4.1 Participants

24 body-abled older users (range 65-86, mean 74.25, SD= 5.8) participated of the experience. User profiles were defined according to the information reported on the initial questionnaire: 8 of them had previous experience and regular use of touchscreen devices. Subjects have been divided into two groups:

- Group A includes 8 subjects who use touchscreen at least once a week (mean age 74.75, SD=6.79), 4 of them use a smartphone and the other 4 use a tablet, all use finger interaction;

- Group B includes 16 novice subjects (mean 74, SD=5.06) who had never or rarely use touchscreen devices before the experiment.

4.2 Statistical analysis

Data is not normally distributed according to the results of Shapiro Wilk test (TM: W= 0.8788, p-value= 2.592e-11; EA: W= 0.7886, p-value= 2.202e-15). By consequence, Mann Whitney U test has been used to evaluate significant effects of user's profiles (Group A and Group B).

Data of each group of subjects is not normally distributed neither according to the results of Shapiro Wilk test: Group A (TM: W= 0.9518, p-value= 0.01409; EA: = 0.8462, p-value= 0.0003436) or Group B (TM: W= 0.8635, p-value= 1.68e-09; EA: W= 0.9189, p-value= 0.0004455).

Data distribution for TM and EA is skewed left. For this reason we detailed median for the tendencies and inter-quartiles (IQR) for the variability.

Friedman test has been used to search for significant differences between the four situations of the study (smartphone or tablet, pen or finger). For the post-hoc analysis, the Wilcoxon signed rank test has been used to evaluate screen size or interaction techniques effects. In this case, a Bonferroni correction has been applied, setting the p-value to 0.0125.

4.3 Time of movement

The statistical analysis show that there is a significant difference of experience of use of touchscreen on time of movement (TM) (Z= 10.51528, W= 5205.5, p-value= 0.002249). The mean time for Group A is 28.3 seconds (SD= 13, median= 27.2, IQR=16.5) and for Group B it is 37.5 seconds (SD= 19.8, median= 30.9, IQR= 19.3). There is a bigger variability among novice users, as observed on **Fig. 1**.

There is a significant effect of the different situations (screen sizes, interaction techniques) of the game on TM for all subjects (chi-squared= 75.8, df= 23, p-value= 1.499e-07), as well as for Group A (chi-squared= 21.5, df= 7, p-value= 0.003096) and for Group B (chi-squared= 50.3382, df= 15, p-value= 1.06e-05). Consequently, we search for effects of interaction techniques and screen sizes.

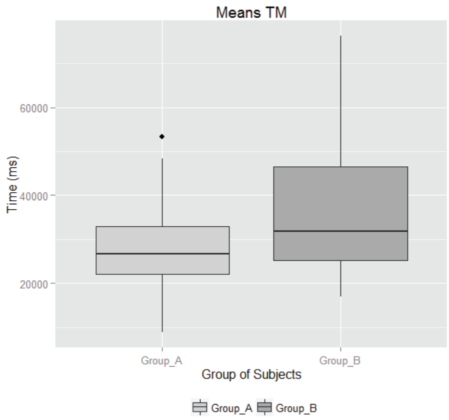

Fig. 1. Time of movement (TM) for experienced (Group A) and novices (Group B)

No significant effect of interaction techniques was found for Group A (Z= 1.869894, V= 364, p-value= 0.06222) neither for Group B (Z= 1.123501, V= 1208, p-value= 0.2626). There was no significant effect of the screen sizes for Group A (Z= -2.262572, V= 143, p-value= 0.02279). But there is a significant effect of screen sizes for Group B (Z= -3.203315, V= 561, p-value= 0.001374). On average, they spent 34.7 s (SD= 18.7, median= 29.6, IQR= 18.1) during interaction on smartphone and 40.3 s (SD= 20.6, median=31.6, IQR= 18.2) on tablet.

The shortest TMs for Group A and for Group B were executed during pen interaction on smartphone (Group A: mean 24.4, SD= 7.9, median= 23.8, IQR=4.8 and Group B: mean 34.9, SD=17.4, median= 27, IQR= 21.9). No significant difference between the two groups was found for any situation, details are presented on **Fig. 2**.

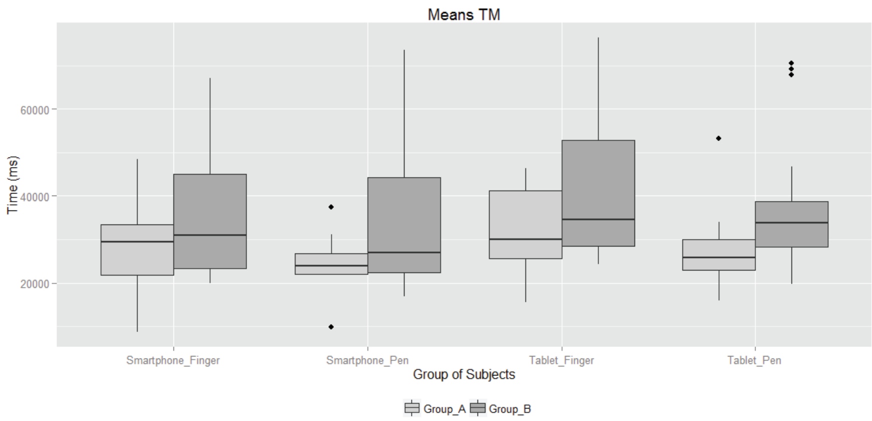

Fig. 2. Time of movement (TM) for experienced (Group A) and novices (Group B) during the different situations of the experience (Smartphone or Tablet with Finger or Pen)

4.4 Errors

There is no significant difference of experience of use of touchscreen on number of errors of accuracy (EA) (Z= 7.595485, W= 4406.5, p-value = 0.3922) as presented on **Fig. 3**. Mean EA for Group A is 10.5 (SD= 12.6, median= 5.5, IQR= 11.3) and for Group B is 12.4 (SD= 14.1, median= 6, IQR= 14.3).

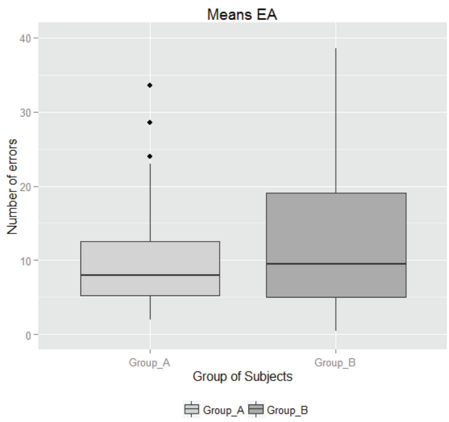

Fig. 3. Errors of accuracy (EA) for experienced (Group A) and novices (Group B)

There is a significant effect of the different situations of the game on EA for all subjects (chi-squared= 70.484, df= 23, p-value= 1.024e-06) as well as for Group A (chi-squared= 20.5945, df= 7, p-value= 0.004419) and for Group B (chi-squared= 44.9778, df= 15, p-value= 7.719e-05). Consequently, we search for effects of interaction techniques and screen sizes.

There are significant effects of interaction techniques (Z= 0.5796671, V= 295, p-value= 0.01105) and screen sizes (Z= 1.76705, V= 358.5, p-value= 0.009706) on EA for Group A. Experienced subjects made more errors of accuracy during interaction with finger (mean= 12.3, SD= 15, median=6.5, IQR= 13) than with pen (mean= 8.7, SD= 9.6, median= 5, IQR= 12). Errors of accuracy were more frequent on smartphone (mean= 13.2, SD= 14.3, median=8.5, IQR= 19) than on tablet (mean= 7.8, SD= 10.2, median= 5, IQR= 6.3).

There is a significant effect of interaction technique (Z= 0.4748128, V= 1111, p-value= 0.01069) on EA for Group B but no effect was found for screen sizes (Z= 0.7055317, V= 1145.5, p-value= 0.04944). Novice subjects made more errors of accuracy during interaction with finger (mean= 14.1, SD= 14.7, median= 7.5, IQR= 15.3) than with pen (mean= 10.7, SD= 13.4, median= 5, IQR= 13.3).

Pen interaction on tablet was the most accurate situation for novices and experienced subjects. The number of EA for Group A was on average 6.25 (SD= 5.7, median= 5, IQR= 7.3) and for Group B it was 8.9 (SD12.4, median= 4.5, IQR= 9.3). The less accurate situation for both groups was finger interaction on smartphone, where average EA for Group A was 15.2 (SD= 16.3, median= 10, IQR= 18.8) and 15.4 for

Group B (SD= 16.4, median= 7, IQR= 17.5). No significant effect of touchscreen experience was found for any situation, details are presented on **Fig. 4**.

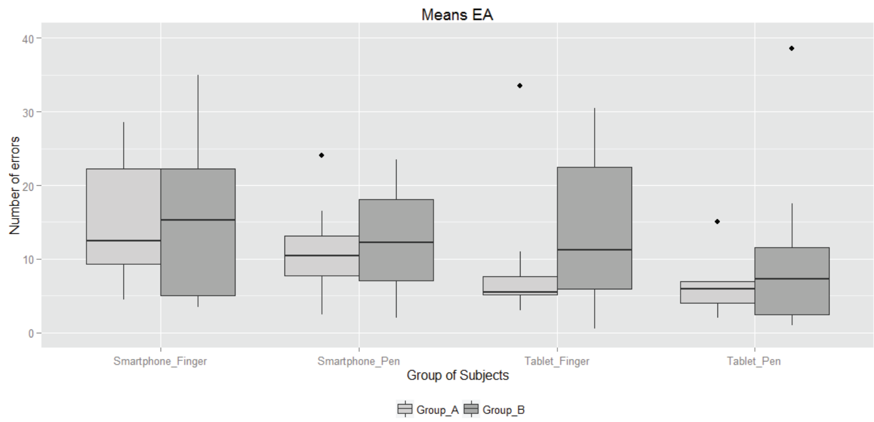

Fig. 4. Errors of accuracy (EA) for experienced (Group A) and novices (Group B) during the different situations of the experience (Smartphone or Tablet with Finger or Pen)

5 Discussion

Novice and experienced subjects were able to complete the tactile puzzle games. Apparently, the familiarity with the task and the metaphor of drag-and-drop helped older adults with and without experience with touchscreen devices to accomplish the interaction on smartphone and tablet, with pen and finger.

The statistical analysis shows that there is a significant difference between the two groups of users on time of movement. Novice older adults spent longer times. There is a significant effect of screen sizes on time of movement only for novice users; they spent less time during interaction on smartphone, where the distances are smaller. The shortest time for both groups was executed during pen interaction on smartphone.

There is no significant difference of use of touchscreen on number of errors of accuracy. There is a bigger variability among novice subjects. A significant effect of interaction technique was found for both groups. They made fewer errors during pen interaction. Effects of screen size were found only for experienced subjects, who were more accurate during interaction on tablet.

Our main hypothesis is partially confirmed: novice spent longer movement times but novice and experienced older adults have similar number of errors on global results. However, some situations of the experience seem to facilitate the interaction for novice subjects. Pen interaction reduced time and error rates for this group. Other studies about tactile interaction of older adults demonstrated that older subjects take longer times but they are not less accurate than younger users [20], who have prior experience with technologies. Maybe using a pen is more natural for novice users. Generally subjects made more errors of placement during finger interaction but the difference is really small for experienced users. As already reported by previous studies about tactile interaction of older adults, the fingertip and the hand can occlude a part of the screen [11]. Experienced subjects would know how to adapt the gesture to avoid errors of accuracy during finger interaction since there are used to interact with fingers. Bigger screen sizes have also been recommended for older adults as bigger targets are easier to acquire [15], even if distances are bigger and so are the deviations [20].

Previous studies evaluating drag-and-drop have demonstrated higher accuracy for this interaction gesture, even if it takes longer times than tapping [11, 16]. Sliding the finger on the screen can increase the confidence of older users because they can better anticipate the acquisition of the targets. Errors of interaction increase considerably the cognitive workload for older users, especially novices who will need to create a strategy for recovering. Errors of accuracy as slipping or missing a target can have severe consequences. For example, missing a target during text entry tasks can cause insertion of characters and more interaction is necessary to correct the word [21]. In addition to that, supplementary manipulation can trigger other errors. For this reason, it is important to evaluate and prevent errors of accuracy during interaction.

Even if subjects were body-abled, aging related changes can affect user's skills, what could explain the variability of performances. Further studies should evaluate the effects of different user' profiles on interaction such as age, education, use of technologies, eyesight and dexterity. A future work for the analysis of ease-of-use of touchscreen should provide a deeper understanding of appropriation of tactile interaction after a longer period of practice or several iterations.

The results demonstrate that drag-and-drop interaction on mobile touchscreen devices is easy to use, confirming previous considerations about the usability of touchscreen for older adults. Potential users consider the ease-of-use for accepting a technology and this factor should persist during the adoption process [22]. Hence, we propose that tactile interaction continuous to be improved and applied on technologies for aging people. In the other hand, as touchscreen seems to be usable for older populations, the problem of limited acceptance and adoption of technologies need to be redressed through other factors. For example, the familiarity of the interfaces and interactions could reduce anxiety for novice users. Adaptive visual displays could also be used to improve the accessibility and reduce error rates. As younger populations have adopted mobile devices, we expect that tactile interaction will be adapted to respond to their needs for a longtime.

6 Conclusion

This study evaluated the ease-of-use of touchscreens by the comparison of novice and experienced older adults. Time of movement and the number of errors of accuracy were assessed during drag-and-drop interaction for achieving tactile puzzle games.

Results show that novice older adults were able to accomplish tactile interaction with longer movement times but not significant difference of error rates when compared to experienced older users. Tactile interaction can be considered ease to use but should be improved to allow older adults to adopt and use technologies for longer times.

Familiar tasks and coherent metaphor for the gesture of interaction can help novice users to better understand and learn interaction. These factors could be used to redress the limitation of acceptance of technologies by older populations. Improving accessibility and usability is necessary to allow older populations to continuously access the benefits of mobile technologies and to prevent digital exclusion.

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